Defining Background Contaminant Levels for Human and Ecological Risk Assessment in Puget Sound and Beyond

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Abstract

Establishing background of contaminants in fish and seafood is a critical task for risk evaluation and management, effecting decisions about resource use and remediation. A proper approach to defining, understanding, and tracking contaminant levels is crucial to human and ecological risk evaluation and risk management. The complexity of the contaminant distributions and sources human (DDTs and PCBs) or of natural origin (mercury, arsenic, nitrogen) requires careful design and implementation of methods to characterize background. Using examples from Puget Sound and other waterbodies, we explore the consequences of different approaches to background characterization. Estimates of background are influenced by sampling and analytical methods such as selection of sampling locations, approaches to data analysis and synthesis, and tissues selected for analysis. Different approaches may yield background exposure or risk estimates that differ by 50% or more. Methodological transparency is essential in data collection and analysis to establish background and to ensure that data are used appropriately in both human and ecological risk assessments. This research was supported by the Consortium for Risk Evaluation with Stakeholder Participation II (US DOE DE-FG26-00NT40938), Center for Child Environmental Health Risk's Research (EPA R 826886-01, NIEHS 5 P01 ES09601-02), and Center for Study and Improvement of Regulation.

Extended Abstract

Establishing background levels of contaminants in seafood is a critical task for risk evaluation and management, affecting decisions about resource use and remediation. A proper approach to defining, understanding, and tracking contaminant levels is crucial to evaluation and management of risks to human and ecological health. Although the concept of "background" may seem simple, considerable complexity exists in the definition, use, and application of the concept. In the realm of risk assessment, the risk questions being asked may also affect designation of background. We describe diverse uses of the term "background," the challenges we encounter using the concept in assessment of risks to human and ecological health from fish, and finally, the lessons of these experiences. We hope to stimulate more rigorous use of background in the science of risk evaluation. This work will appear in full in the journal *Human and Ecological Risk Assessment* in late 2003 (Judd et al. in press a)

The complexity of contaminant distributions and sources—human (DDTs and PCBs) or natural (mercury, arsenic, nitrogen)—requires careful design and implementation of protocols to characterize background. When human activities increase concentrations of materials (e.g., mercury at Minimata, Japan; radon from mine tailings; excess nitrogen runoff to nearby water bodies when fertilizers are applied to increase agricultural production), their presence above background levels can make them environmental contaminants of concern. Other contaminants, such as DDT and its metabolic byproducts, are solely derived from human industrial activity so background levels are always zero under this "natural" definition.

Yet the concept of background is far more complicated than is depicted by a simple natural vs. human-influenced dichotomy. A state agency may decide on the need for regulation of a wastewater treatment plant by determining if contaminant levels increase downstream of the plant's effluent pipe. The background level against which one must evaluate the need for regulation includes the sum of natural and human-derived levels of contamination in water reaching the treatment plant from upstream. Similarly, Port Susan in Puget Sound, WA, USA is sometimes used as a "background" site (D.R.E.B.W.Q.A.T. 1999). Port Susan is considered relatively pristine, when compared to other locations in Puget Sound even though PCBs and DDT are present in fish from this site (D.R.E.B.W.Q.A.T. 1999). As these examples illustrate, background levels of contamination may, depending on context, derive from natural, human-induced, or combined sources of environmental contaminants.

The example of fish contaminated with PCBs reveals the complexities of establishing background for human and ecological risk assessment. Four components important for consistency in establishing background for contaminants in fish are selection of location for sampling, selection of tissue for analysis, method of compositing samples, and selection of analytical method. Approaches for each of these may be different within and between human and ecological risk assessment and may lead to widely different estimates of risk and risk management decisions. Protocols for establishing background must be transparent to avoid inferences about risks with data not appropriate to those inferences. Data collected to examine human health risks, for example, often cannot be used to evaluate ecological risks.

The selection of sample location or region influences the level of contamination determined to be background. In a recent Washington State Department of Health study (Washington State Department of Health 2001), a background level of PCBs in fish was needed for the eastern part of the state to compare to PCB levels in fish from a highly contaminated site on the Spokane River. PCB levels in trout from the Northern Rockies Intermontaine Basin were more than three times higher than levels in trout from Western Washington (Washington State Department of Health 2001). Thus the selection of site has major implications for background estimation.

The selection of tissue for establishing background can also have major impacts on contaminant level estimates. Livers, often the focal tissue for analyses of risks to fish or ecological health (NOAA 1988; West *et al.* 2001), concentrate many toxicants at the highest levels. Fish livers are not commonly consumed by people, although some populations, notably some Asian and Pacific Islanders and Native Americans (Sechena et al. 1999; Toy et al. 1996), regularly consume whole fish. In the absence of a system relating liver and muscle levels of contaminants or classes of contaminants for species consumed, fish liver data are not useful for assessing exposure and health risk for most populations. An example of the influence of tissue selection on estimates of background comes from a study of PCB concentration (sum of detected Aroclors) in English sole (*Parophrys vetulus*). Average PCB concentrations in muscle tissue at a non-urban site in Puget Sound (North Hood Canal) were much lower (6.7 parts per billion, ppb) than concentrations in liver tissue at the same site (125.2 ppb) (West et al. 2001). Over the long term and at a number of sample sites, PCB muscle tissue concentrations in Puget Sound English sole are below 30 ppb for non-urban sites. In contrast, average PCB levels in English sole liver tissue always exceeded 50 ppb and were generally well above 100 ppb (Puget Sound Water Quality Action Team 1998; West et al.2001). Some shellfish also concentrate contaminants in digestive organs which are eaten by some populations, and inclusion of these organs leads to exposure and risk estimates that may vary by 10 fold or more (Judd et al.., 2002). Failure to explicitly define and carefully compare the same tissues to establish background can lead to flawed risk assessments.

Decisions about compositing fish may have significant effects on estimates of background as well. The method advocated by USEPA (1995) and followed by many government agencies calls for equal portions of tissue from multiple individuals in composite samples. A simulation analysis of compositing protocols shows that USEPA's recommended approach may substantially underestimate consumer exposure. When data from five Spokane River rainbow trout (*Oncorhynchus mykiss*) (Washington State Department of Health 2001) were composited by the USEPA method (equal-sized samples of individual fish), Aroclor 1248 concentration was 440 ppb. A second approach assumed the composite was representative of the relative mass of each individual; Aroclor 1248 concentration was 25% higher at 550 ppb. The size of composited fish influences estimates of Aroclor concentrations and thus exposure and risk.

The effects of analytical method selection are apparent when exposures are considered as background "risks," particularly when many of the samples are reported as non-detect values (Judd et al.in press b, Judd *et al*., 2003). In a human health risk assessment of fish consumption from the Willamette River, two different analytical methods were used to measure PCB concentration as Aroclors and as individual congeners. Estimates of cancer risk based on dioxin-like PCB congeners and their associated toxic equivalency factors (TEFs) were 50% higher than those based on Aroclors (EVS 2000). Because remediation options are often considered in terms of reducing exposure to "background" levels of risk, selection of analytical method could significantly influence risk management decisions.

Using examples from Puget Sound and other waterbodies, we explored the consequences of different approaches to background characterization. The risk questions and context considered by researchers affects determination of background. Estimates of background are influenced by sampling and analytical methods such as selection of sampling locations, approaches to data analysis and synthesis, and tissues selected for analysis. Different approaches may yield background exposure or risk estimates that differ by 50% or more. In human health risk assessment the emphasis is on risk to individual humans whereas ecological risk assessment tracks (or should track) a much broader array of issues. These include risks from presence of chemical contaminants and from other non-contaminant consequences of human actions (Karr 1991; 1995a; Karr and Chu 1999; NRC 2001). They also range from risks to the well being of individuals to populations and assemblages of species as well as to ecosystems in space and time (Karr, 1995b). Historically, human health risk assessment tended to be more precise but narrow in conception while ecological health risk assessment was typically broader but with less quantitative precision. For both, definition of background level influences what people feel is a reasonable or acceptable risk level from a given exposure. The more narrow approach of human health needs to be integrated within the larger context of ecological risk assessment.

Risk assessors must recognize the diversity of background contexts and be sure they understand the opportunities and limits associated with both recent and historical databases. They must also recognize the importance of devoting careful thought to considering sampling and analytical approaches before a project is initiated so data can be used in diverse situations. Methodological transparency is essential in data collection and analysis to establish background and to ensure that data are used appropriately in both human and ecological risk assessments.

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